CHAPTER 11
Mammographic Quality Standards

KEY TERMS
adverse event  gray scale processing  serious complaint
annotations and measurements  image inversion  target composition
beryllium window  magnification  tomosynthesis
compression  Mammography Quality Standards Act  tissue equalization
customer  postprocessing  workflow
emission spectrum  extended processing

OBJECTIVES
At the completion of this chapter the reader should be able to do the following:

• Explain the difference between dedicated mammography equipment and conventional equipment
• Describe the composition of the x-ray tube target in mammographic equipment
• Discuss the advantages of compression during mammographic procedures
• Describe the image receptor systems currently used in mammography
• Describe the basic differences between film/screen mammography and full-field digital mammography
• Indicate the quality control tasks relating to the radiologist and the medical physicist
• Describe the quality control duties of the mammographer on a daily, weekly, quarterly, and semiannual basis
• Describe the various components of a Food and Drug Administration/Mammography Quality Standards Act inspection

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Mammography is soft tissue radiography of the breast. It requires different equipment and techniques from conventional radiography because of the close similarities among anatomic structures (low subject contrast). Low kilovolt (peak) (kVp) in the 20- to 30-kVp range must be deployed to maximize the amount of photoelectric effect and enhance differential absorption. The side effect of using lower kilovolt (peak) exposure factors is correspondingly higher milliampere-second (mAs) values, which increase the total radiation dose to the patient. The American College of Radiology recommends that the average glandular dose for a 4.2-cm thick breast should be less than 300 millirad (3 milligray [mGy]) per view for film/screen image receptors used with a grid. If no grid is used, the average glandular dose should be less than 100 millirad (1 mGy) per view. Because the glandular tissue of the breast is inherently radiosensitive, care must be taken to minimize radiation exposure through dedicated equipment and quality control procedures.

DEDICATED MAMMOGRAPHIC EQUIPMENT

X-Ray Generator

The x-ray generators used in mammographic studies should be dedicated solely to mammographic imaging (Fig. 11-1). All current mammographic imagers are high-frequency x-ray generators (see Chapter 7) that are smaller in size and less expensive than earlier single and three-phase mammographic units. High-frequency x-ray generators also provide exceptional exposure reproducibility, which is essential for consistent image quality. The kilovolt (peak) range available on most units is between 20 and 35 kVp, and typical x-ray tube currents are about 80 to 200 mA. Exposure times are usually about 1 second but can be as long as 4 seconds for dense or thick breasts or for those with implants. For a normal compressed breast (4.5 cm), a typical x-ray tube voltage is 25 kVp with an mA/exposure time combination of about 120 mAs. All systems with film/screen image receptors must be equipped with an automatic exposure control (AEC) system that consists of two to three sensors to regulate the optical density (OD) of the resulting image. Each film/screen system should provide an AEC mode that is operable in all combinations of equipment configuration provided (e.g., grid, nongrid, magnification, nonmagnification, and various target-filter combinations). The positioning or selection of the detector should permit flexibility in the placement of the detector under the target tissue. The size and available positions of the detector must be clearly indicated at the x-ray input surface of the breast compression paddle. The system also must provide a means for the operator to vary the selected OD from the normal (zero) setting. The x-ray tube/image receptor assembly must be capable of being fixed in any position and not undergo any unintended motion or fail in the event of power interruption.

X-Ray Tube

Modern mammographic x-ray units use rotating anode x-ray tubes just as conventional radiographic units do. However, some significant differences are present including the x-ray tube window, target composition, focal spot size, and source-to-image distance (SID).

**X-Ray Tube Window.** X-ray tubes used in conventional radiographic, fluoroscopic, and computed tomography units incorporate a window made primarily of glass (which is essentially silicon with an atomic number of 14). Because relatively high kilovolt (peak) exposure factors are used in these studies, absorption of low-energy x-rays in the window material is acceptable and actually desired. Mammographic x-ray tubes use a thinner glass window or a beryllium window (atomic number of 4), which is less likely to absorb the low kilovolt (peak) x-rays used in mammographic procedures. The inherent filtration of the beryllium is about 0.1-mm aluminum (Al) equivalent compared with 0.5-mm Al equivalent for standard radiographic tubes.

**Target Composition.** Conventional radiographic x-ray tubes use a target composition of a tungsten-rhenium alloy. A mixture of x-rays produced by both bremsstrahlung (the slowing down of the projectile electron,
causing a wide range of x-ray energies) and characteristic radiation (x-rays created by electron transitions between orbits resulting in specific or discrete energies) exists in the x-ray beam created with these x-ray tubes. This effect can be demonstrated with an x-ray emission spectrum graph (Fig. 11-2). This wide band of energies may be desirable in conventional radiography but is not desirable in mammography because of the low subject contrast. Factors affecting the x-ray emission spectrum graph include milliampere, kilovolt (peak), added filtration, target material, and voltage waveform/ripple.

**Milliampere.** The factor of milliampere changes the amplitude of the curve (height of the y-axis) but not the shape of the curve (Fig. 11-3).

**Kilovolt (Peak).** The factor of kilovolt (peak) changes both the amplitude and the position of the spectrum curve. An increase in kilovolt (peak) shifts the spectrum to the right, indicating higher energy values (Fig. 11-4).

**Added Filtration.** Because filtration affects x-ray quality, the effect on the x-ray emission spectrum is similar to that of kilovolt (peak). If filtration is increased, the amplitude decreases and the spectrum shifts slightly to the right (Fig. 11-5).

**Target Material.** The amplitude and shape of the emission spectrum graph vary with any changes in the atomic number of the target material. If the atomic number increases, the continuous portion of the spectrum (bremsstrahlung) increases slightly in amplitude, especially to the high-energy side, whereas the discrete portion of the spectrum (characteristic x-rays) shifts to the right (Fig. 11-6). The target materials used in mammographic x-ray tubes can include tungsten, molybdenum, rhodium, or a combination of these.

**Tungsten (Atomic Number, 74).** Tungsten produces a wide band of x-ray energies including some that

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**FIGURE 11-2** Emission spectrum for tungsten-rhenium target. keV, Kiloelectron volt.

**FIGURE 11-3** Effect of mA on emission spectrum. keV, Kiloelectron volt; mA, milliampere.

**FIGURE 11-4** Effect of kVp on emission spectrum. keV, Kiloelectron; kVp, kilovolt (peak).

**FIGURE 11-5** Effect of added filtration on emission spectrum. Al, Aluminum; keV, Kiloelectronvolt.

**FIGURE 11-6** Effect of target material on emission spectrum. keV, Kiloelectron volt; z, atomic number.